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Logging Methods and Costs in the Southern Appalachians

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INTRODUCTION

Most timber operators have a fair idea of their total logging costs but have not taken the time to examine the separate cost components. Consequently, they do not know where to start reducing costs when the profit margin shrinks below the acceptable limit. Logging factors such as tree size, species, accessibility, type of equipment, and method of operation are all-important in determining final costs; hence the effect of each should be known to the appraiser and operator. Furthermore, logging cost information by tree size is needed before the financial maturity of a tree or a stand can be determined.

Formal study of logging costs in the Southern Appalachian region is not new. Most of the early studies, however, are no longer useful because of radical changes in equipment and methods. In some cases results were expressed in terms of dollars and cents, and were of value for a few years only--until wage rates and other costs changed. In 1946 Shames (8) presented the results from a single but not necessarily average operation in this region. The present study is more complete in showing how production costs vary between species or species groups, and in comparing the cost of alternate methods, so that an operator can choose the best method and the most suitable equipment for his own conditions.

The results reported here are based on studies of some thirty different logging operations conducted within a 75-mile radius of Asheville, N. C., from 1947 to 1952.

NATURE OF STUDY

The object of the study was to determine the relationship of species, tree size, type of equipment, alternate methods, and other factors to the time required for felling, bucking, skidding, loading, and hauling of Appalachian species--largely hardwoods. The study includes a comparison of hand and power log making, team and tractor skidding, hand and power loading and

truck hauling over different classes of roads. Stand volume cut or left was not included as a study item.

As indicated above, these studies were made on many different logging chances representing all types of operators and job sizes. Most of the studies included samples taken at different seasons so that seasonal effects were averaged. When the first hand-felling studies were started in 1947, power saws were just coming into use (3); consequently, they were not studied then. However, they were carefully studied in 1951 and 1952. Team and tractor skidding were likewise studied at different times, except that both were studied on the same job when possible.

The location of the studies ranged from flat land to steep mountainsides. Differences in topography usually result in differences in species occurrence also. Consequently, our studies included all of the common species and a few of the uncommon ones. Stands of mixed hardwoods predominated, however, so that special efforts were required to obtain data on such species as white pine. The types of equipment used and the operating methods studied were the ones most commonly used. Such operating methods as cable logging were too rare and expensive to justify much study time.

A check study of seven of the larger logging operations within the study area was made just before publishing this report to compare computed costs with current contract or force-account costs, and adjustments were made when it was considered advisable.

For practical purposes we have used trees of average height for a given diameter in tabulating felling and bucking time per M board feet by species groups. The smaller trees averaged only one log, while trees 24 inches d.b.h. and over contain three logs. A change in the number of logs per tree compared with the average used will affect time and costs. More logs will reduce the time per M board feet, and fewer logs will increase it.

The average tree volumes used in this report are derived from those computed for the North Carolina Survey Unit No. 4 (mountain area), by T. C. Evans of the Southeastern Forest Experiment Station. Different average tree volumes will also change the time and cost requirements per M board feet, for felling and bucking especially, and also skidding and loading to a lesser extent. For example, an increase of 30 board feet in the average tree volume at 14 inches d.b.h. will reduce the time requirements per M board feet some 25 percent.

Delay times were the usual ones encountered on the job and do not include such lost time items as storms or other unusual delays exceeding an hour. Some of these will be discussed below under the various operations.

Throughout the study the International 1/4-inch log rule is the basic unit of measurement. All time and cost data, unless otherwise indicated, are per thousand board feet (hereafter referred to as M b.f.). To convert these data to Scribner scale, approximately 10 percent more time will have to be added to all diameters. See table 77 in Reynolds' publication (6) for a comparison of time and cost for the various log rules.

The term log making includes felling, limbing, and bucking. This phase of the study covers both hand and power equipment. The hand equipment is the type used in the mountains for the past 50 years or more. It consists of a two-man crosscut saw 5 to 6 feet long, an ax (usually double bitted), a pair of iron wedges and an iron or wooden maul for driving the wedges. The power equipment included both one- and two-man gasoline-motor-driven chain saws, but even the one-man saw was operated by two men in the felling stage. Three makes of power saws were included, but comparison of the relative efficiency of the different saws was beyong the scope of this study. Crew size for each method ranged from two to four men. Tree diameters ranged from 8 to 50 inches, and tree length ranged from one to five logs per tree.

The number of trees cut by each method was approximately the same (164 by hand, 188 by power), and species distribution was also similar. The hand-tool data were collected on 13 operations, while the power tools included only six operations.

Separate time was kept for each phase of the operation by tree and log size. While the pocket watch was accurate enough for hand tools, a stop watch was used with power saws. Regression analyses were made for each phase of log making and then combined to produce the times shown in table 1 for each tree d.b.h. class. In the final regression equations given below, T is log-making time in man-minutes per tree, and D is d.b.h. of the tree.

Hand methods, hard hardwoods:

$$T = .17D^2 + 29.75 \qquad \text{(I)}$$

Hand methods, pine and soft hardwoods:

$$T = .145D^2 + 24.1 \qquad \text{(II)}$$

Power methods, all species:

$$T = .055D^2 + 4.6 \qquad \text{(III)}$$

The final terms of the above equations include average delay time, which amounted to 22.9 man-minutes per tree for hand methods (Equations I and II), and 3.0 man-minutes for power methods (Equation III).

The man-hour requirements shown in table 1 and figure 1 are for average workers in average timber, with no lost time for travel or bad weather. Shames (8) found such lost time amounted to 8 percent of the day's total time. Costs in table 1 are based on hourly rates which are derived in tables 7 and 8 of the appendix.

The major factor affecting log-making time was the type of equipment used. Man-hour requirements for log making with power saws averaged only about one-third those for hand tools (fig. 1), while dollar costs per M b.f. were only about half of those for hand tools (table 1).

Table 1.--Relation of tree size to time and cost of felling, trimming, and bucking trees of difference species groups with hand and with power tools

HAND

D.b.h. (Inches)	Hard hardwoods				Pine and soft hardwoods			
	Time[1] per tree	Vol. per tree	Time per M b.f.	Cost per M b.f.	Time[1] per tree	Vol. per tree	Time per M b.f.	Cost per M b.f.
	Man-hours	B.f.	Man-hours[2]	Dollars[3]	Man-hours	B.f.	Man-hours[2]	Dollars[3]
10	--	--	--	--	.65	40	15.0	14.25
12	--	--	--	--	.75	80	9.2	8.75
14	1.05	70	14.0	13.30	.88	140	6.6	6.25
16	1.22	110	10.8	10.25	1.02	200	5.2	4.95
18	1.41	160	8.8	8.35	1.18	280	4.4	4.20
20	1.63	220	7.6	7.20	1.36	370	3.8	3.60
24	2.13	350	6.2	5.90	1.79	560	3.1	2.95
30	3.04	590	5.2	4.95	2.58	910	2.7	2.55
36	4.17	800	4.8	4.55	--	--	2.6	2.45

POWER

D.b.h. (Inches)	Time per tree	Vol. per tree	Time per M b.f.	Cost per M b.f.	Time per tree	Vol. per tree	Time per M b.f.	Cost per M b.f.
10	--	--	--	--	.162	40	3.50	5.25
12	--	--	--	--	.210	80	2.20	3.30
14	.258	70	3.25	4.90	.258	140	1.80	2.70
16	.316	110	2.75	4.10	.316	200	1.60	2.40
18	.375	160	2.40	3.60	.375	280	1.40	2.10
20	.445	220	2.15	3.20	.445	370	1.30	1.95
24	.590	350	1.75	2.60	.590	560	1.10	1.65
30	.903	590	1.55	2.30	.903	910	1.00	1.50
36	1.270	860	1.45	2.20	1.270	--	.95	1.40

1/ The time data are based on two-man crews already on the job.

2/ Man-hours are curved values rounded to nearest .10 m.h. for hand and nearest .05 m.h. for power tools.

3/ Dollar costs are based on hourly rates of $0.95 and $1.50 for hand and power tools respectively, and are rounded to nearest 5 cents (see appendix tables 7 and 8 for derivation).

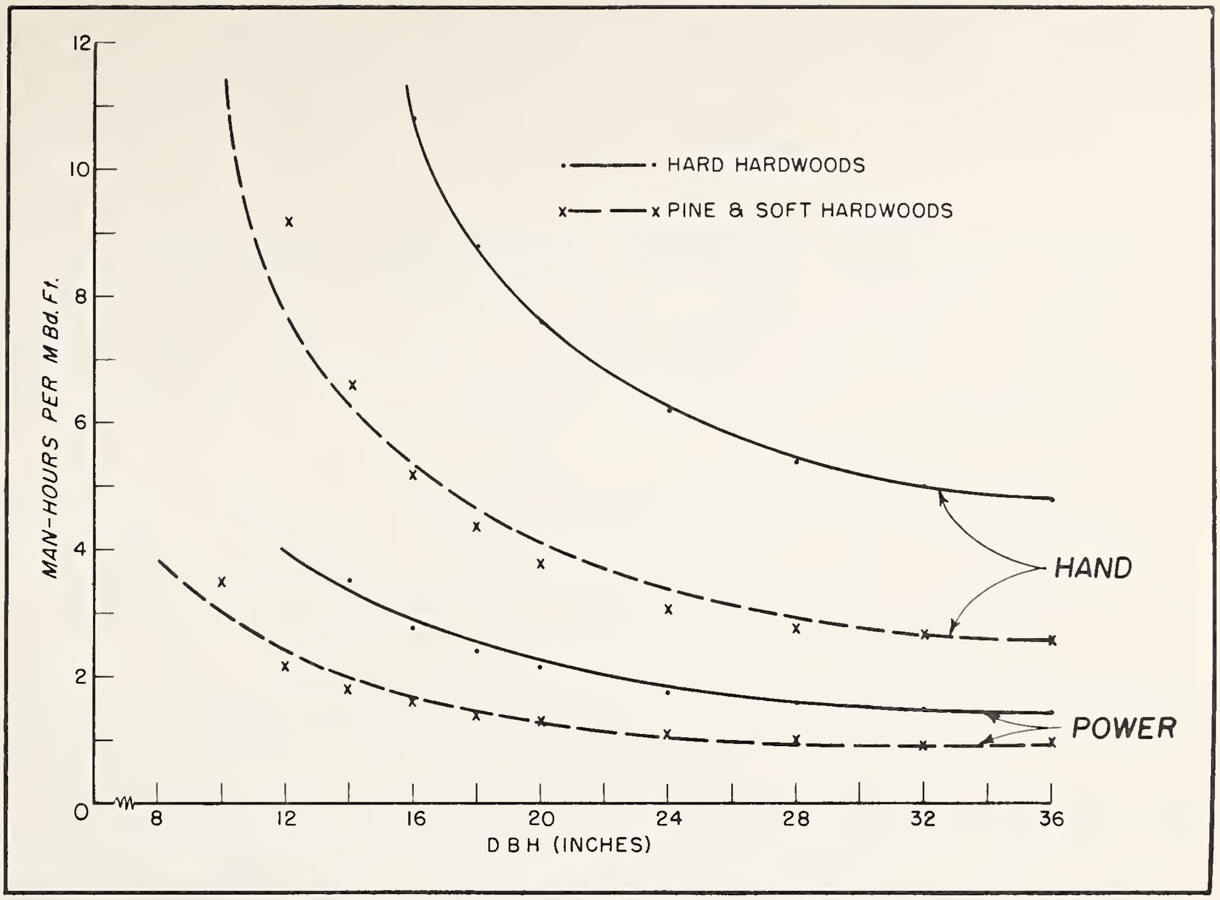


Figure 1.--Relation of felling, trimming, and bucking time to tree size for different species groups and for hand and power tools.

For a given type of equipment, tree size had the most important bearing on log-making time. For example, the time for all species for hand methods decreased with tree size from 9 hours per M b.f. for 14-inch trees to less than 4 hours for 36-inch trees. With power saws, tree size had somewhat less effect on log-making time (2-3/4 man-hours for 14-inch trees and 1-1/2 man-hours for 36-inch trees).

The above relationships are for trees of average merchantable height for their diameter class. Within a given diameter class, the tree volume and number of logs have an additional effect on log-making time. The taller the tree and the greater its volume, the less is the time required per M b.f. for log making.

The third factor influencing log-making time was species of tree. The major variation was accounted for by grouping the species into (1) hard hardwoods, and (2) pine and soft hardwoods. Time requirements per M b.f. for a given diameter class were about twice as high for hard hardwoods as for yellow pine and soft hardwoods when cut with hand tools. Limited data indicate that time requirements for white pine are similar to those for soft hardwoods.

Further examination of the data showed that the difference between species groups was less with power saws than with hand tools (fig. 1). Since felling time alone was about the same for all species, group differences became important only in trimming and bucking operations.

The difference between species groups is much greater when the results are expressed in terms of man-hours per M b.f. than as man-hours per tree. The reason is that for a given diameter class, the pine and soft hardwood group has a considerably higher average volume per tree over which to prorate the log-making time, as shown in table 1.

Size of crew was an important factor in the time requirements for log making with hand tools. Our observations show that the addition of a third man to a crew is rarely profitable. Lost time averages more per tree with three or more men than with two. Consequently three- and four-man crews increase the basic man-hour requirements for hand tools from one-third to one-half.

Contrary to the findings with hand tools, the size of the power-saw crew had little effect on man-hour requirements per M b.f. within the range of crew size studied (two to four men). However, Weitzman (11) found a one-man crew to be more efficient than a two-man crew on a power-saw operation in West Virginia.

Delay time is more important for power than for hand tools, since the fixed cost for equipment represents a much larger proportion of total hourly costs in the case of power equipment. Delay times were found to average much less in the case of power saws.

Incentive appeared to play a large part in the output of power-saw crews. Those crews working by the hour took no longer to cut down or buck a tree than those working at a contract rate, but the number and length of delays between trees was much higher for the hourly paid employees.

While the time and cost data shown apply to average conditions, they must be increased for the more difficult logging chances. Thus, on steep mountain jobs where travel was difficult and trees were scattered and short, costs were found to be double or even triple those shown in table 1.

SKIDDING

When this study was started, ground skidding was the only accepted method for moving logs from the stump to the mill or roadside over much of the Southern Appalachian area. Since then a few cable logging jobs have been completed but they are quite rare and usually require a large capital outlay. Another and newer method, still rare in this area, is the use of the arch or rubber-tired sulky pulled by a tractor. This device and method is being used on the Fernow Experimental Forest.[1/]

The study reported here sampled the most common types of motive power now in use in the Appalachians--teams, light tractors (D2 and TD6), and medium tractors (D4 and TD9). The range of conditions sampled for each type of equipment is tabulated as follows.

1/ A part of the Mountain State Research Center (Northeastern Forest Experiment Station), with headquarters at Elkins, West Virginia.

		Team	Light tractors	Medium tractors
Trips	number	335	72	60
Load size				
Minimum	board feet	20	200	150
Maximum	board feet	800	900	1650
Average	board feet	200	475	650
Distance				
Minimum	chains	1	4	5
Maximum	chains	16	20	50
Average slope	percent	0-100	0-40	0-50

The job of skidding was timed in five parts: (a) hooking, (b) travel to the landing, (c) unhooking, (d) return time, (e) delays. Additional data for each turn included diameter, length and species of log, length of the trip, and degree of slope.

Separate regression analyses were made for travel time and hooking time for each type of equipment with various distances, load sizes, slopes, and species combinations. Below are the regression equations used for computing skidding time in crew minutes per trip (T) for different skidding methods:

Team:

$$T = 4.52 + .67D + 1.48\,(VmDS) + .60\,(VmDC) + 1.61L$$

D2 and TD6 tractors:

$$T + 6.54 + .53D + 1.08\,(VmDS) + .338\,(VmDC) + 4.40L$$

D4 and TD9 tractors:

$$T = .36 + .94D + 1.6L$$

D is the distance in chains--one way
L is the number of logs
S is sine of the slope in degrees
C is cosine of slope in degrees
Vm is load volume in M b.f.
Delay time is included in the initial constant of each equation

Only the variables which had a significant effect are included in a given equation. Note that the more the horsepower the fewer the important variables; with ample power the degree of slope and load volume become less important.

Skidding time (converted from minutes per trip to crew-hours per M b.f.) for the three types of equipment are compared in figure 2. Although loads of different board-foot volume are shown, the diagram is restricted to loads of two or four logs in order to simplify the comparisons.

Skidding time was least for the D4 and TD9 tractors. Teams were somewhat faster than D2 and TD6 tractors except for larger loads skidded over long distances (fig. 2).

But skidding time per M b.f. is not the whole story, nor is it the answer desired by the operator or the timber appraiser. Consequently, crew-hours were converted to dollars per M b.f. and are illustrated in figure 3. In this figure average load sizes are assumed to be 200, 400, and 800 board feet, while full loads are assumed to be double the average or 400, 800, and 1600 board-feet for team. small tractor and medium tractor respectively. Medium tractors were consistently the cheapest motive power for all distances and load sizes, and teams were second. The D2-class tractor doesn't seem to be a very practical machine for the Southern Appalachians. In skidding costs it ranks a poor third because of high operating cost in relation to its speed and load size. Subsequent comparisons with respect to load size, distance, slope, and other factors, therefore, will be made only between the team and the larger tractors (D4, TD9).

Size of load was the most important single variable studied for each type of equipment, ranking ahead of distance as a cost factor. A study of the data in figure 3 or table 2 will show that when load size is held constand, doubling the distance increases cost per M b.f. from one-fourth to three-fourths--averaging one-half. When distance is held constant, halving the load size more than doubles the cost per M b.f. This matter of loading to capacity can hardly be overemphasized whether for team or tractor.

Following is a brief summary of load sizes by type of equipment as found in this study. Team loads averaged 90 b.f. for 227 trips, all of which were skidded less than 9 chains and up to 20-percent slope. For longer trips and steeper slopes the loads averaged 280 b.f. for 27 loads. For 78 different trips, timed by Shames (8), the team loads averaged 225 b.f. and all but four of these were skidded less than 7 chains.

In the case of the D4, full loads up to 1600 b.f. were sometimes skidded, but the average load for all 60 trips was only 650 b.f. Steep slopes usually prevent maneuvering for full loads. There was also a tendency to underload on the short hauls. This tendency was especially noticeable on one job where for 23 trips averaging 12 chains or less and 12-percent slope or less, an average of only 300 b.f. per trip was hauled, but for longer trips and steeper slopes on this same job the loads averaged 740 b.f.

Although load size in terms of board feet is a convenient figure to work with, tree d.b.h. and its relation to skidding time and cost is much more useful to the timber appraiser and the more skilful timber contractors. This is true because tree size is basic to most uses of logging costs; hence skidding costs are desired for the same unit. Tree size has an important bearing on skidding costs because the small logs from small trees limit the board-foot load that can be skidded on one trip. In constructing table 2

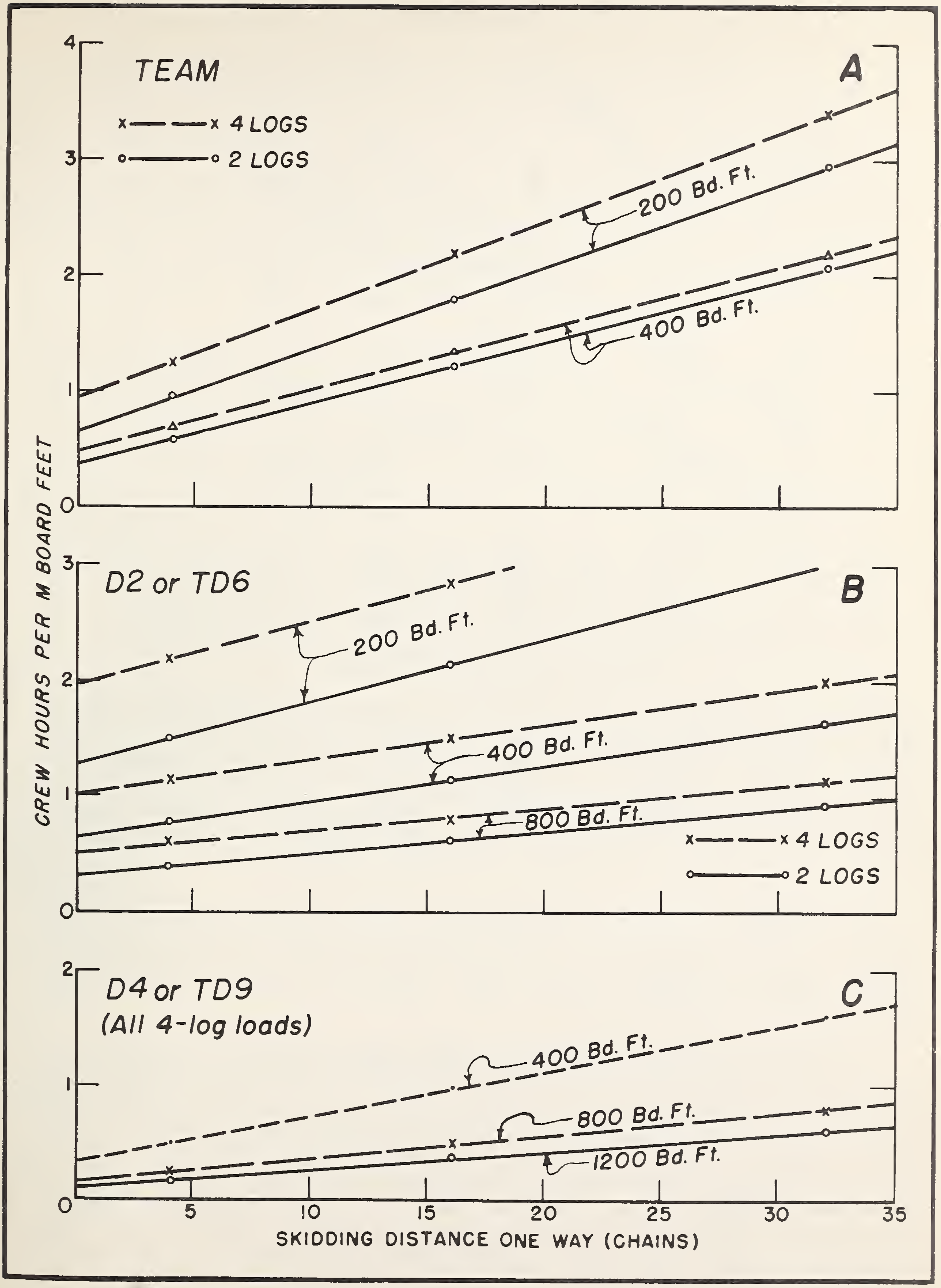


Figure 2.--Skidding time per M b.f. on 20-percent slope for various load sizes, distances, and for two types of equipment.

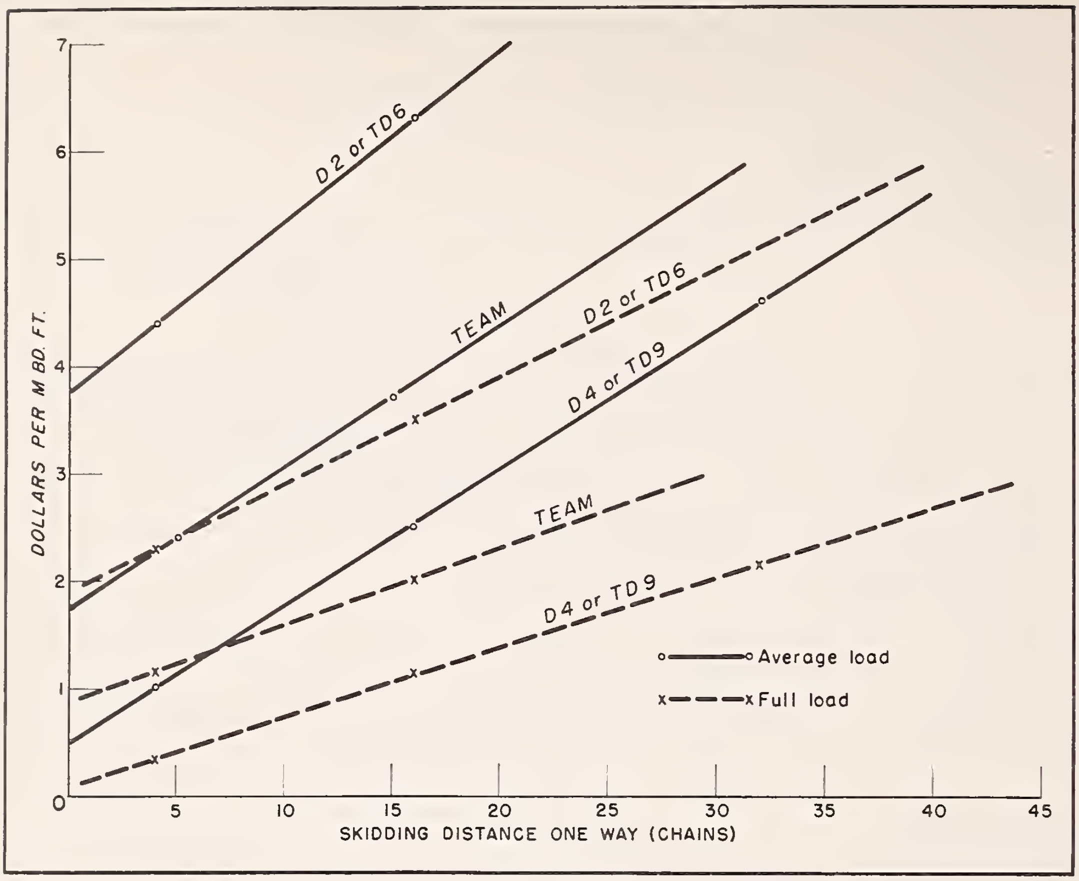


Figure 3.--Skidding costs per M b.f. on 20-percent slope for team, D2-, and D4-class tractors with average and full loads.

and figures 3 and 4, full loads of small trees were considered to be six logs for the team and eight for the tractor. Hooking time was prorated for the appropriate number of logs per trip. Tractor load volumes were limited to double those for the team, which is conservative though in line with the usual practice observed. Minimum team (no swamper) and maximum tractor rates were used--the latter, because mountain logging usually wears out such equipment faster than average use.

Difference in size of load is the major reason for the difference in cost of skidding between our study and a recent TVA study (9). We used full loads for all tree sizes in computing team and tractor costs, whereas they used smaller loads. This difference resulted in skidding costs double or triple ours.

A study of figure 4 will show that team skidding is cheaper only for small trees and short distances, and then only when no swamper time is included. The addition of a swamper for only half time makes tractor logging cheaper at all distances for trees larger than 16 inches. Even with no swamper time for the teams, the larger trees (20 inches and over) can be moved cheaper by tractor (D4 and TD9). The fact that tractor loads are assumed to be only double those for team, whereas they could well be three times the team load, makes the tractor showing rather conservative in these comparisons. Furthermore, the tractor's economy is not realized with small loads. Extremely rough ground or scattered timber will also result in higher costs--up to double those shown in table 2.

Table 2.--Skidding costs per M b.f. by tree size on 20-percent slope

Distance and d.b.h.	Team				Medium tractor		
	Load size	Crew time		Cost at[1/] $1.85, all species	Load size	Crew time	Cost[1/] at $5.10
		Hardwood	Pine				
	B.f.	Hours	Hours	Dollars	B.f.	Hours	Dollars
4 chains							
12 inches	200	1.30	1.20	2.30	400	.60	3.05
16 "	250	.95	.85	1.65	500	.35	1.80
20 "	300	.80	.70	1.40	600	.22	1.10
25 "	300	.70	.55	1.15	600	.20	1.00
30 "	400	.55	.45	.90	800	.15	.75
36 "	600	.45	.30	.75	1200	.08	.40
8 chains							
12 inches	200	1.60	1.50	2.85	400	.75	3.80
16 "	250	1.20	1.10	2.15	500	.45	2.30
20 "	300	1.05	.90	1.80	600	.35	1.80
25 "	300	.95	.75	1.55	600	.30	1.55
30 "	400	.80	.60	1.30	800	.20	1.00
36 "	600	.70	.45	1.00	1200	.15	.70
16 chains							
12 inches	200	2.15	2.05	3.90	400	1.05	5.35
16 "	250	1.80	1.60	3.15	500	.70	3.55
20 "	300	1.60	1.35	2.70	600	.55	2.80
25 "	300	1.50	1.10	2.40	600	.50	2.55
30 "	400	1.35	.85	2.05	800	.35	1.80
36 "	600	1.20	.70	1.75	1200	.25	1.25
32 chains							
12 inches	--	--	--	--	400	1.40	7.15
16 "	--	--	--	--	500	1.15	5.85
20 "	--	--	--	--	600	1.00	5.10
25 "	--	--	--	--	600	.90	4.60
30 "	--	--	--	--	800	.65	3.30
36 "	--	--	--	--	1200	.45	2.40

1/ Values rounded to nearest 5 cents. For derivation of hourly costs, see tables 8 and 11 in the appendix. Team cost does not include swamper. Tractor rates used are the maximum.

Actual travel time per M b.f. was not appreciably affected by the number of logs pulled for either team or tractor. It was only in the hooking phase of skidding that the number of logs became important. Each additional log added about 1.6 minutes of hooking time for both team and large tractors. The number of logs for teams especially and for tractors practically, is limited by the number of sets of grabs or dogs which can be dragged. Three sets of grabs (or enough to make a train of four logs) was the usual maximum for a team, and five sets was the usual limit studied for a tractor. Although a few tractors were observed carrying more than five sets, the resultant load of logs, hitched abreast rather than tandem, knocked down an undue amount of reproduction and exposed more soil to erosion than necessary.

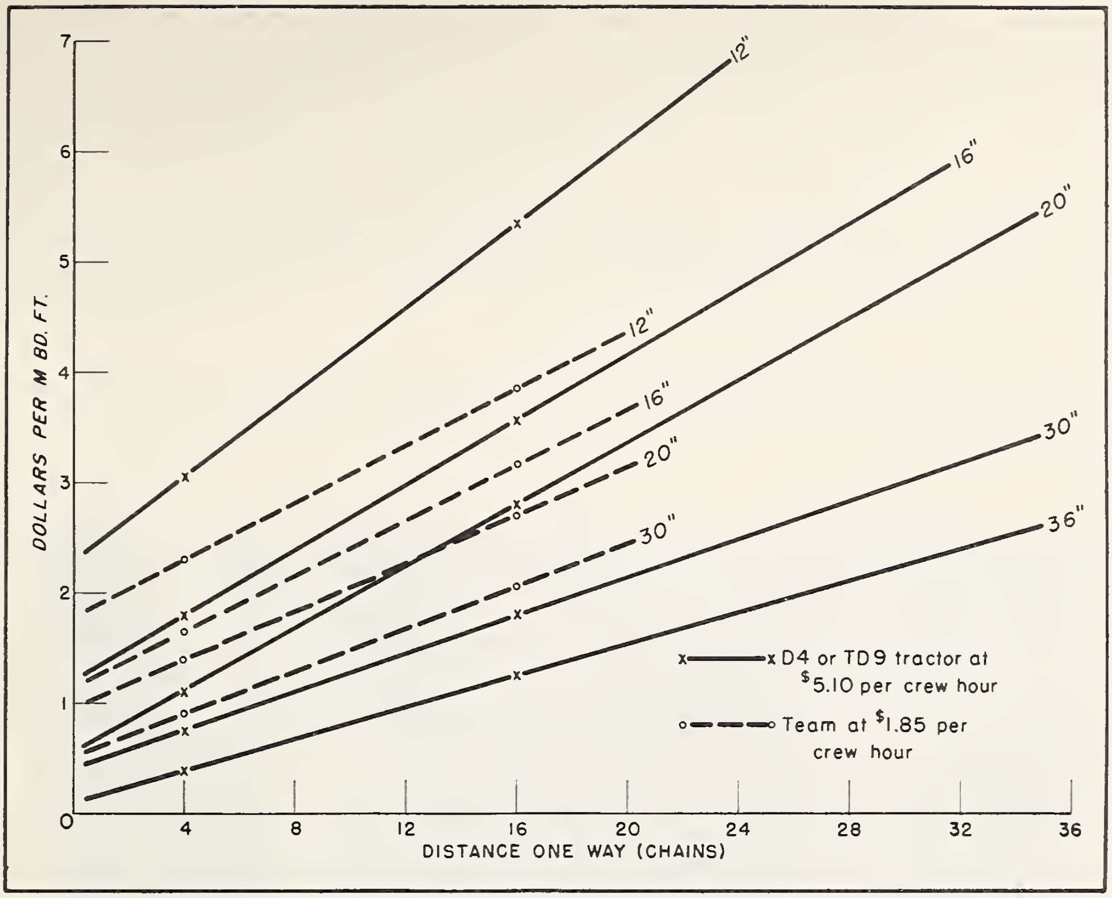
Steepness of slope increased the skidding time per M b.f. for teams because of the added rest time required by the team when returning uphill. The added uphill travel time of the team is not offset by increased downhill speed. There is, however, an offsetting influence of steep slopes not covered in the studies reported earlier, and that is on load size. Larger loads can be skidded down steeper slopes, although this principle is often overlooked in practice. While 300 board feet may be a capacity load for a team on level terrain, 1000 board feet may not be a full load when the slope is 100 percent.

Tractor skidding time per M b.f. did not increase significantly with increased steepness of slope up to 40 percent. However, manufacturers do not recommend trying to operate tractors on adverse slopes exceeding 50 percent, because of unsafe operating conditions and rapid loss of tractor efficiency.

Species composition had little effect on skidding time except for team skidding. Here skidding time was apparently slightly less for small loads of hard hardwoods than for pine or soft hardwoods, while for average loads there was little difference. For large loads (400 or more b.f.), team skidding time was about one-third less for pine or soft hardwoods than for the same size load of hard hardwoods. Species composition did not significantly affect skidding time with tractors.

Delay time in skidding is a relatively small item in contrast to its importance in felling and bucking. Total delay time for teams averaged 2.8 minutes per trip compared with a delay time average of 2.1 minutes per trip for all sizes of tractors. The delay times include only those connected with the working time and do not include delays due to bad weather or travel to and from the job. Shames (8) found the latter type of delays amounted to 30 percent of the total possible work time. Although our observations indicate this amount is probably too high, an increase of 20 percent in the cost data shown in table 2 and figures 3 and 4 would be justified.

A regular ground skidder is usually much cheaper to operate on uphill skidding than is a tractor because of lower hourly cost and a faster take-up drum. Power skidding uphill for distances up to 6 chains (400 ft.) can be done at a cost roughly comparable to that shown for tractors (D4 or TD9) skidding downhill the same distance. Beyond 400 feet, power skidding time and cost go up very rapidly.



4.--Skidding costs per M b.f. for team and D-4 class tractor, by tree size, 20-percent slope.

Data furnished by the Caterpillar Co. indicate that a tractor equipped with a sulky and logging tree length loads can double hourly or daily production at a cost increase of only 10 percent. Observation and tentative data from the Fernow Experimental Forest indicate that soil damage for this method is less than for any of the direct skidding methods studied.

TRUCK LOADING

Truck loading by hand and by power were both studied. Truck sizes ranged from 1-1/2 tons to 2-1/2 tons. Hand loading was all from natural banks or prebuilt log cribs. No team or cross-haul loading was found. The power loading was all done by means of a "skidder-loader." Such a machine is commonly constructed of scrap material by a local shop man and roughly resembles the "Loggers Dream."2/ It usually consists of a fairly new Ford or Chevrolet motor mounted in back of the cab of an old truck. A pole A frame is mounted on the extreme rear end of a truck. The extra motor powers a single drum located between the A frame and the extra motor (fig. 5).

2/ A patented machine manufactured by the Taylor Machine Works of Louisville, Miss.

Loading is done with the aid of power equipment on all but the smallest operations. Although the hand-loading part of our study was rather limited, it failed to show any radical disadvantage compared with power loading. Probably the greatest advantage of power is in flat country, where bank loading points are nonexistent or so far away that skidding to them is uneconomical. In the mountains, bank-loading spots can usually be found without much difficulty, and power loading is more efficient only in coves, in other level topography, or when logs are both skidded and loaded by the same machine.

Power loading data were collected for 29 loads containing a total of 415 logs which scaled 47 M b.f., while hand loads totaled 9.5 M b.f. in 13 loads.

Figure 5.--Power loader in operation.

Loading time per load for power equipment was found to be closely related to the number of logs per load and the volume of the load in M b.f. (fig. 6). In addition there are the relatively fixed time elements of binding, unloading, and delay. These total 10 minutes per load regardless of number of logs or size of load.

The extent to which small logs increase the loading time per M b.f. is shown in the following tabulation from figure 5, using a constant load volume of 1500 b.f.:

Load	Man-hours	Man-hours per M b.f.
5 logs	1.2	0.8
10 logs	1.5	1.0
20 logs	2.1	1.4

Time and cost data for other load sizes and number of logs can be obtained by computation. Separate computations for trees of the two species groups were made, but the time and dollar differences were so small that only the average for all species is shown in table 3.

TRUCK HAULING

Hauling is the first item of logging cost to be discussed which is independent of tree or log size, assuming full loads are being hauled. Load size is usually limited by a combination of legal load restrictions and the quality of woods roads. It can be readily seen that once the logs are loaded other factors than log size, such as type of road and distance, are the primary factors controlling hauling costs. Furthermore, this phase is the only one on which we have done but little original work. We have, however, checked travel time by road types. Operating costs are based on Reynolds' (7) recent studies.

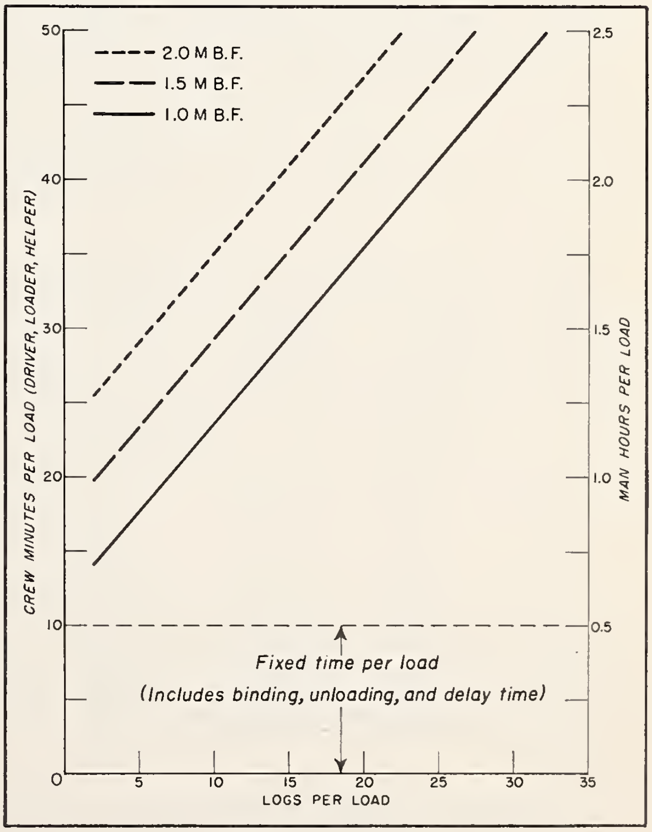


Figure 6.--Power loading time per M b.f. for trucks carrying loads of 1, 1-1/2, and 2 M b.f., as affected by the number of logs per load.

Truck operating expenses have been added to hourly fixed costs prorated according to travel time and the total cost computed for various distances. These costs and the corresponding travel times are shown in table 4. Since these costs are not appreciably affected by load volumes ranging from 1 to 2 M b.f., the user should remember to divide total costs by M b.f. hauled to get costs per thousand board feet.

Table 3.--Truck loading time and cost with power loader in relation to tree size, with loads of one M b.f.

D.b.h. (Inches)	Logs per M b.f.	Time[1] per load	Loading cost[2]	Truck stand-by cost[3]	Total cost per load[4]
	Number	Crew-hours	Dollars	Dollars	Dollars
12	25	.69	1.90	1.14	3.05
16	13	.45	1.24	.74	2.05
20	9	.37	1.02	.61	1.60
24	6	.31	.85	.51	1.35
30	4	.27	.74	.45	1.15
36	2-1/2	.24	.66	.40	1.05

1/ Loading time per load derived from regression formula: Time in crew-minutes per load, including loading and unloading = 11.44 M b.f. + 1.2 number logs.
2/ Loading cost is based on a machine rate of $2.75 per crew-hour (See table 10).
3/ Loading time in crew-hours multiplied by $1.65 per hour (includes driver) for truck stand-by time. (See table 11 for derivation of truck rate.)
4/ Values curved and rounded to nearest 5 cents.

Table 4.--Truck hauling time and cost[1] per trip

Trip dist. 1 way (Miles)	Woods road				Hard surface road			
	Total[2] travel time	Run[3] expense at $0.50	Fixed[4] cost at $1.65	Total[5] cost	Total[2] travel time	Run[3] expense at $0.24	Fixed[4] cost at $1.65	Total[5] cost
	Hours	- - - Dollars - - -			Hours	- - - Dollars - - -		
1	.33	.50	.54	1.05	.10	.24	.16	.40
2	.67	1.00	1.10	2.10	.20	.48	.33	.80
3	1.00	1.50	1.65	3.15	.30	.72	.49	1.20
4	1.33	2.00	2.20	4.20	.40	.96	.66	1.60
5	1.67	2.50	2.75	5.25	.50	1.20	.80	2.00
10	3.33	5.00	5.50	10.50	1.00	2.40	1.65	3.05
15	5.00	7.50	8.25	15.75	1.50	3.60	2.50	6.10
20	6.67	10.00	11.00	21.00	2.00	4.80	3.30	8.10
30	--	--	--	--	3.00	7.20	4.95	12.15
40	--	--	--	--	4.00	9.60	6.60	16.20

1/ Time and cost data are for 1-1/2- or 2-ton trucks. Costs per trip are for loads of 1 M b.f. and should be increased for larger loads.
2/ Based on average speeds of 6 m.p.h. on woods roads and 20 m.p.h. on paved roads.
3/ Running expenses are from table 11 (appendix) and have been doubled for round-trip values.
4/ Fixed costs are from table 11.
5/ These are costs per load of 1 M b.f. and are rounded to nearest 5 cents.

It has been found that hauling time per mile and the resultant cost varies inversely with the hardness of the road surface and alignment--other conditions remaining equal. Earlier studies (2,5) show travel time for three or four types of roads. Reynolds' report (7) shows cost data for only two--(a) woods, (b) graded dirt or better. Shames data (8) indicate approximately equal round-trip speed per mile for gravel and black-top pavement. Probably two road classes (highway and woods) are adequate.

Since there are several classes of woods roads, the following brief description will explain our version of a woods road. Such a road is only roughly graded--but not surfaced. Consequently, it is not an all-weather road, but can be used most of the year if it is not traveled during or immediately following rains. Grades are generally favorable to the loaded truck. Speeds up to 10 m.p.h. are possible on the better stretches but speeds of 3 to 8 m.p.h. are more common. Reynolds (7) found that running costs per mile on graded dirt or better roads (including pavement) are approximately half of those for woods roads. Although we have travel time for lower quality roads than described above, we do not have accompanying operating costs. However, we did increase operating costs for mountain dirt roads by approximately 20 percent over Reynolds' data.

TOTAL LOGGING COST PER M B.F. BY TREE SIZE

It is recognized in appraisal work that not all logging costs can be assigned on a tree-size basis. However, since the basic data for determining average tree size are collected while cruising and marking trees for sale, full advantage should be taken of this information to make a more realistic and accurate appraisal.

There are several factors affecting logging cost which are essentially independent of tree size. These factors include: weather, which in turn affects both travel time and work time; accessibility, including access to the sale area and to the trees; road construction cost and length of haul; supervision; and finally, a margin for profit and risk. Since these factors are not directly assignable to tree size, they will be added where appropriate in the following set of costs (tables 5a, 5b) for mechanized mountain logging under a selected range of conditions.

It is assumed that power saws, tractors, and trucks will be used to good advantage by experienced workers, under the normal range of operating conditions found in this area. An indication of the spread of costs for each operation will be found under the separate columns headed easy and hard chance, as shown in tables 5a and 5b.

Although a range of conditions is covered by these average costs, the range is by no means complete. Consequently, an appraiser or operator who uses the data will have to exercise judgment in applying them to his specific case. Thus, while time and costs are shown for both pine and hardwoods, costs for mixtures will have to be interpolated.

Delays due to bad weather and walking to and from the job were not included in the time study or in table 5. Some of this extra time is discussed in the various text sections, e.g., 8 percent for log making, 20 percent for skidding. For convenience a single average figure of 15 percent could be added to total costs in table 5 before computing profit and risk. If logging costs are desired for a short job during the winter months, then all costs shown should probably be increased by one-third to one-half because of slower travel time and more difficult working conditions in the woods.

As the tree size increases, costs go down, at least within the size range sampled in this study. If variable costs only, including felling, skidding, and loading, are considered, dollar costs per M b.f.

Table 5a.--Logging time and cost per M b.f. for selected tree sizes, methods, and distances

Tree d.b.h. (Inches)	Power felling and bucking[1]						Skidding (D4 tractor)[2]				Loading[3]	
	Pine or soft hardwoods			Hard hardwoods			3 chains		30 chains		1 M b.f.	
	Time	Easy chance	Hard[4] chance	Time	Easy chance	Hard[4] chance	Time	Cost	Time	Cost	Time	Cost
	Man-hours	- - Dollars - -		Man-hours	- - Dollars - -		Crew hours	Dollars	Crew hours	Dollars	Crew hours	Dollars
12	2.50	3.75	7.50	4.0	6.00	12.00	.54	5.15	1.37	7.00	.69	3.05
16	1.70	2.55	5.10	2.9	4.35	8.70	.32	3.40	1.10	5.60	.45	2.05
20	1.30	1.95	3.90	2.3	3.45	6.90	.20	2.65	.94	4.80	.37	1.60
24	1.10	1.65	3.30	1.9	2.85	5.70	.16	2.20	.79	4.00	.31	1.35
30	.95	1.40	2.80	1.6	2.40	4.80	.13	1.70	.59	3.00	.27	1.15
36	.90	1.35	2.70	1.4	2.10	4.20	.07	1.20	.44	2.25	.24	1.05

1/ Time read from curves shown in figure 1. Hourly rate of $1.50.
2/ Costs read from figure 4. Time derived by dividing costs by hourly rate of $5.10.
3/ Loading time and cost are from table 3. Hourly rate of $2.75, but dollar column includes truck standby cost at $1.65 per hour.
4/ Hard chance costs are twice the easy ones and are for use under such severe logging conditions as steep rocky areas, or those covered with dense laurel.

Table 5b.--Total cost per M b.f. for selected tree sizes, methods, and distances

(In dollars)

Tree d.b.h. (Inches)	Cost of felling, bucking, skidding, and loading				Road bldg.[1] & hauling[2]		Total including 20-percent margin[3]			
	Pine or soft hardwoods		Hard hardwoods		Easy chance	Hard chance	Pine or soft hardwoods		Hard hardwoods	
	Easy chance	Hard chance	Easy chance	Hard chance			Easy chance	Hard chance	Easy chance	Hard chance
12	11.95	17.55	14.20	22.05	4.05	17.30	19.08	41.82	21.78	47.22
16	8.00	12.75	9.80	16.35	4.05	17.30	14.46	36.06	16.62	40.38
20	6.20	10.30	7.70	13.30	4.05	17.30	12.30	33.12	14.10	36.72
24	5.20	8.65	6.40	11.05	4.05	17.30	11.10	31.14	12.54	34.02
30	4.25	6.95	5.25	8.95	4.05	17.30	9.96	29.10	11.16	31.50
36	3.60	6.00	4.35	7.50	4.05	17.30	9.18	27.96	10.08	29.76

1/ Easy road building cost is $600 for 1 mile. This sum divided by the cut (600 M b.f.) equals $1.00 per M b.f. Cost of a hard-chance road for 2 miles is $3000, or $5.00 per M b.f.

2/ Easy haul cost based on 1 mile woods road plus 5 miles highway ($3.05 total) plus $1.00 for road building. Hard haul cost based on 4 miles woods road plus 20 miles highway ($12.30 total) plus $5.00 for road building.

3/ Profit margin includes allowance for supervision.

for 24-inch trees average half as much as those for 12-inch trees regardless of species, and costs for 36-inch trees are only one-third those for 12-inch trees. These cost relationships are graphically illustrated in figure 7. Tree d.b.h. has an even greater effect on hand-logging costs than on machine-logging costs.

Detailed logging-cost information by tree size has another important application in addition to stumpage appraisals. In order to predict the earning power of standing trees of known growth rate, and the size at which they are financially mature, the forest manager needs to know among other things the cost of conversion for different tree sizes. The information presented here will provide the conversion-cost data needed in financial maturity computations.

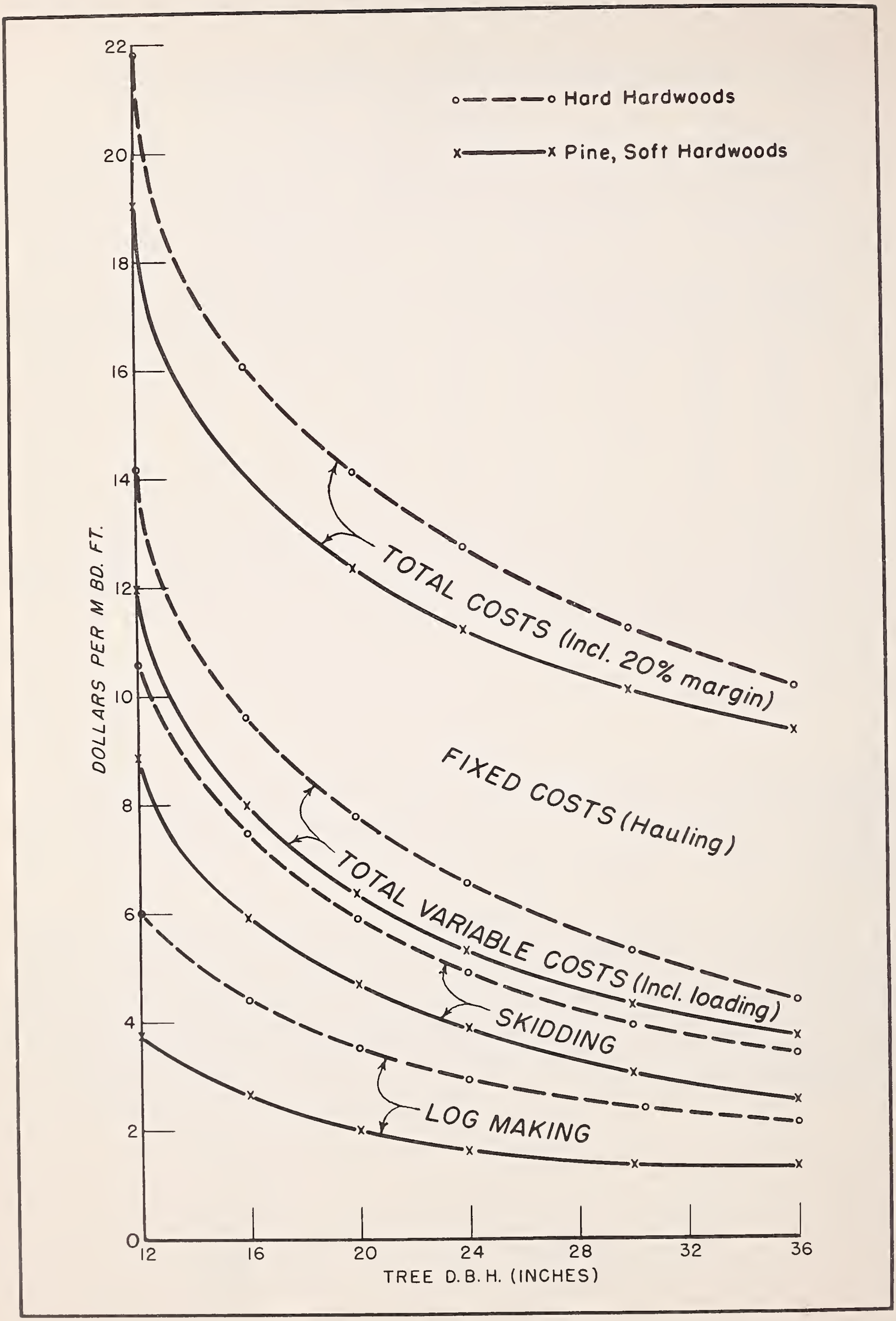


Figure 7.--Power logging costs per M b.f. by tree size. Based on easy-chance data, tables 5a and 5b. Skidding distance, 3 chains.

SUMMARY

In the log-making phase of this study it was shown that the power saws enabled men to produce logs in one-third the time required for hand tools, and at one-half the cost. These savings hold for both pine and hardwoods, and for most diameters. Tables and curves of time and cost per M b.f. are shown for various tree sizes, for two species groups, for both hand and power methods.

Skidding time per M b.f. is determined chiefly by load size and secondarily by distance traveled, for all skidding methods. In team skidding, the number of logs, species group, and slope are also important factors. As a general rule, teams should not be required to skid trees averaging 16 inches d.b.h. or larger and they should not skid more than 15 chains (1000 feet), except on slopes over 50 percent, where tractors are unsafe and inefficient. Cost tables and diagrams for both team and tractor logging for selected tree sizes and distance are presented.

The skidding phase of this study emphasizes the desirability and economic necessity of loading to capacity, regardless of motive power.

Loading time per M b.f. with power equipment is determined largely by number of logs per load and board-foot volume of load. Tables of loading time and cost for various load volumes and tree sizes are presented. Hauling time and costs for woods and highway classes of roads are also shown.

Variable costs (log making, skidding, and loading) will usually comprise from one-fourth to three-fourths of the total, depending largely on the road-building and hauling costs. Detailed tables show the components of total logging cost by tree size for mechanized operations under easy and difficult working conditions. Total variable costs for 36-inch trees are only one-third and for 24-inch trees only one-half the costs for 12-inch trees.

Intelligent supervision is a necessity particuliarly in mechanizing logging. The use of large crews in log making and skidding tended to reduce the output per man. Proper work planning will insure full utilization of time by both men and machines. This combination will make logging both easier and safer for the worker as well as saving money for the operator.

Brief statements on road construction costs and sawmilling requirements by tree size are given in the appendix section. In addition the appendix contains tables of hourly equipment rates for sawing, skidding, loading, and hauling. These may be used in recomputing hourly rates where costs are different from those given.

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APPENDIX

Road-Construction Costs

Mountain roads suitable for truck travel on all but snowy or rainy days and immediately thereafter can be built for as little as $300 per mile in favorable locations. Such locations include those with moderate slopes (up to 20 percent), practically no drainage problems, and no rocks or a few loose ones per mile. Construction costs per mile for mountain truck roads will average closer to $600 or $700 per mile, however. Surfacing, even with local creek gravel usually costs an extra $1000 to $1500 per mile. Road-construction costs increase rapidly as the slope increases and especially as the amount of solid rock increases, until a feasible limit of about $2500 per mile is reached for unsurfaced graded truck roads. Somewhere near this point road construction costs are prohibitive and direct skidding or cable logging are the only alternatives.

On the Fernow Experiment Forest, near Elkins, West Virginia, skid roads suitable for tractor and sulky use, but too narrow for truck use, are built for approximately $80 to $250 per mile (10).

Sawmilling

The information in this section, as in the one on roads, is included for the benefit of appraisers and to complete the picture of logging and milling costs.

A recent study made by the Forestry Relations personnel of the Tennessee Valley Authority (4) included 58 mills in three size classes well distributed over the Tennessee Valley. In the small mills (those with 4 men and 65 h.p. or less) each of the variables studied (species, log diameter, and log length) were important. In the medium-size mills (those with 6 men and 85 h.p.) species differences were less important, probably because of an abundance of power. Lost time is very important to all classes of sawmills, as pointed out by Darwin and Thurmond (4).

The following table of time and cost per M b.f. is based on the TVA study, and data are for medium-size mills sawing hard hardwoods.4/ Time for lumber grading, stacking, or hauling is not included in the man-hours shown below. The cost data are derived by multiplying the crew hours by the hourly rate of $6.30 for a 6-man crew.

Table 6.--Sawmilling time-and-cost data per M b.f., by tree size

Tree d.b.h. (Inches)	Av. log d.i.b.	Crew hours per M b.f.1/	Milling cost per M b.f.1/	Total cost per M b.f.2/
	Inches	Hours	Dollars	Dollars
12	9	2.3	14.50	31.00
16	12	1.7	10.70	24.30
20	15	1.5	9.50	21.10
24	18	1.1	6.90	17.50
30	21	1.3	8.20	20.00

1/ Milling time only. Time and cost data from "Circular Sawmills in the Tennessee Valley Region" by Paul H. Lane. Forest Products Research Society Proceedings 5: 17-23. May 1951.
2/ Difference between milling cost and total cost consists of capital, materials, and overhead--including handling.

4/ In this study they found that pine and soft hardwoods cost about 10 percent less per M b.f. to saw than do hard hardwoods.

Table 7.--Computation of total hourly cost for two-man crosscut crew

		Hourly cost
Investment		
2 axes ($10.00), 2 pair wedges ($5.00), 1 hammer ($5.00), 2 crosscut saws ($20.00) = $40.00		
Fixed cost per hour (200 days X 8 hours = 1600 hours)		
Depreciation $40.00 ÷ 1600 hours	$	.025
Maintenance 1/		.075
Subtotal	$	.100
Operating cost per hour		
Wages, 2 men at $0.80	$	1.60
Plus Soc. Sec., Workmen's Comp., etc. at 10%		.16
Subtotal	$	1.76
Total cost per crew hour	$	1.86
Cost per man-hour (rounded)	$	.95

Table 8.--Computation of total hourly cost for two-man power-saw crew

		Hourly cost
Investment $450 for 5 h.p. 40" saw, gas can, files, etc.		
Fixed cost per hour (200 days X 8 hours = 1600 hours)		
Interest at 6% on 1/2 of investment ÷ 1600 hours	$	.01
Depreciation of $450 ÷ 1600		.28
Maintenance, parts and labor 2/		.67
Insurance or risk 2/		.02
Subtotal	$	.98
Operating cost		
Gas, oil, wedges, 2/ etc.	$	.24
Labor, 2 men at $0.80 + 10% (Social Security, etc.)		1.76
Total cost per crew hour	$	2.98
Cost per man-hour (rounded)	$	1.50

1/ Details of maintenance are from F. C. Becker, Jr. (1).
2/ Based on data from R. R. Reynolds (7).

Table 9.--Computation of total hourly cost for team and teamster

Investment		
Team and harness	$300	
Average life, 4 years. Annual depreciation	75	
Fixed cost (200 days X 8 hours = 1600 hours)		Hourly cost
Depreciation of $75 ÷ 1600 hours		$ .05
Interest and taxes		.01
Subtotal		$ .06
Operating costs		
Annual feed bill $1100, shoes $50, medicine $25 harness repair $50, tool replacement $50.		
Subtotal $1300 ÷ 1600 hours		$ .80
Teamster at $0.90 plus 10% Social Security, etc.		.99
Subtotal		$ 1.79
Total cost		$1.85

Table 10.--Computation of total hourly cost for power skidder-loader operator, and helper

	Skidding and loading	Loading only
Investment		
Truck, drum, motor, tongs	$ 2000	
Trade-in value after 6 years (junk)	200	
Amount to be depreciated in 6 years	$ 1800	
	Hourly cost	
Fixed cost		
Yearly depreciation of $300 ÷ 1600 hours	$ .19	
Int. at 6% (average investment), taxes	.06	
Subtotal	$ .25	$ .15
Operating cost--skidding		
1 cable 5/8 in. X 900 ft. at $285, chokers and hooks at $6 X 6 per year = $320 ÷ 1600	$ .20	$ .15
Fuel-gas at $0.30 per gal. X 1-1/2 per hour	.45	.30
Oil and grease	.08	
Repairs and labor (estimated)	.17	.15
Subtotal	1/ .90	.60
Labor		
Operator at $1.00, helper at $0.80 + 10% for Social Security, etc.	$ 1.98	$ 1.98
Total hourly cost	$ 3.15	$ 2.73
Total man-hour cost (rounded)	$ 1.60	$ 1.35

1/ Costs may vary ± 15 percent for hard or easy skidding chances.

Table 11.--Computation of total cost per hour and per mile for light logging truck (such as Ford or Chevrolet) and driver

Investment	1-1/2 ton	2 ton
Truck only ($630 for tires included below under running cost)	$ 1670	$ 2022
Locally made bed	100	100
Subtotal	$ 1770	$ 2122
Trade-in value after 2 years	1370	1620
Amount to be depreciated in 2 years	$ 400	$ 500
Fixed cost	Annual	
Int. at 6% on 1/2 investment	$ 85	$ 100
License, North Carolina	160	175
Taxes, North Carolina	20	25
Insurance or risk at 4% of cost 1/	95	110
Total	$ 360	$ 410
	Daily	
Daily cost at 200 days	$ 1.80	$ 2.05
Daily depreciation at 350 and 400 days 1/	3.45	3.40
Daily driver at $0.90 + 10% Social Security, etc.	7.90	7.90
Total daily cost	$ 13.15	$ 13.35
Hourly cost (8 hours)	1.64	1.67
Average	$1.65	
Running cost 1/ per mile	Pavement	Log road
Tires	$ .06	$ .12
Gas and oil	.03	.07
Repairs and labor	.03	.06
Total	$ .12	$ .25

1/ Based on data from R. R. Reynolds (7).

Table 12.--Computation of total hourly cost for tractor and operator

Investment	D2	D4	D6
Tractor f.o.b. Asheville (ready to go)	$ 4810	$ 6300	$10050
Winch f.o.b. Asheville (no cable)	1240	1475	1825
Subtotal	$ 6050	$ 7775	$11875
Dozer blade and controls	2000	2325	2725
Total	$ 8050	$10100	$14600
Trade-in value after 5 years	1860	2250	2500
		Hourly cost	
Fixed cost, tractor and winch 1/			
Depreciation 10,000 hours	.619	.785	1.21
Int., ins., taxes	.183	.237	.354
Total fixed	.802	1.022	1.564
Operating costs, 1953 average 1/			
Fuel at $0.14 per gal. (no tax)	.224	.280	.434
Gas for starting	.030	.030	.030
Oil	.034	.036	.050
Grease at $0.15 per pound (incl. winch)	.026	.041	.057
Cable for winch	.155	.199	.265
Repairs and labor (incl. winch)	.508	.649	1.024
Total variable	.977	1.235	1.860
Total fixed + operating cost (average)	1.78	2.26	3.42
Easy work = - 15%	1.50	1.90	2.90
Hard work = + 23%	2.20	2.80	4.20
Operator at $1.00, $1.25, $1.50 plus 10% for Social Security, etc.	1.10	1.38	1.65
Helper at $0.75, $0.85, $1.00 plus 10% for Social Security, etc.	.83	.94	1.10
Total (rounded)	1.90	2.30	2.75
Total all costs			
Average	3.30	4.55	6.15
Easy	3.00	4.20	5.65
Hard	3.80	5.10	6.95
Added rate when blade is used	.22	.24	.26

1/ Data from Asheville agency Caterpillar Tractor Co., January 1953.

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